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Managing for Fish and Fire: A Balancing Act in the Gila National Forest

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RESEARCH SUPPORTING SOUND DECISIONS

Gila trout. Credit: Stephanie Coleman, USDA Forest Service.

Managing for Fish and Fire: A Balancing Act in the Gila National Forest

Summary

The Gila National Forest in southwestern New Mexico harbors two imperiled aquatic species in its mid-to-high elevation streams, the Gila chub and the Gila trout. Modern and historical land use pressures, and the introduction of non-native fishes, have reduced the range of the Gila trout to a handful of headwater streams. The remaining populations are highly fragmented. The Gila National Forest was an early pioneer in the use of naturally ignited wildfire to achieve resource benefits. Fish populations can be harmed by fire in some cases, however, even when they have evolved with fire. This occurs when populations dwindle and fish habitat connectivity changes through introduction of non-native fish and human impacts downstream, which sometimes make it difficult for fish to migrate to a more favorable location. A retrospective study using satellite sensor and weather information has documented the effects of forest composition, elevation and slope, snow pack, and seasonal and annual variability in precipitation on burn severity in the Gila. Information on past burn severity may help resource managers plan for actions before and during fire seasons to ensure the long-term survival of the Gila trout and Gila chub. In addition, predicting the likelihood and location of severe fire and potential debris and ash flows can help managers decide which streams are best suited to support fish populations for the long term. The ultimate aim is to bolster populations of native trout and promote connectivity of habitat where the fish stand a good chance of thriving. The fate of the endangered chub is even more precarious.

Key Findings

- In the Gila National Forest, fires are frequently ignited by lightning during short dry spells in the spring and are more likely to burn severely at higher elevations and on northern-facing steep slopes.
- After wildfire, heavy downpours during summer monsoon season can lead to erosion and massive debris and ash flows that kill fish.
- Smaller, isolated fish habitat in streams prone to post-fire erosion may require more intensive interventions such as translocation and restocking with hatchery fish to protect them from fire.

***A wilderness…is hereby recognized as an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain.* —Excerpt from the Wilderness Act, 1964.**

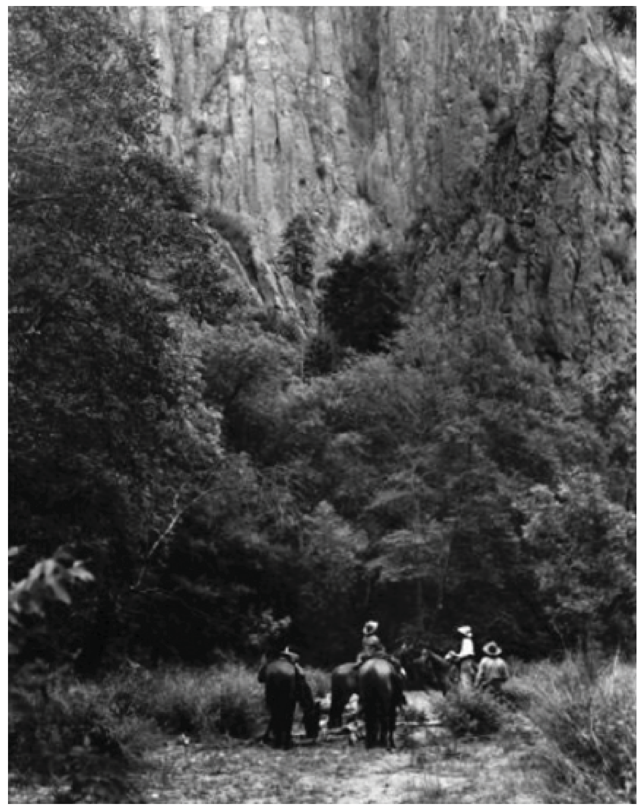
Introduction

In 1924, at the urging of the naturalist Aldo Leopold, 750,000 acres (300,000 hectacres) of the Gila National Forest were declared the first Wilderness and Primitive Area by the Forest Service. Both the Gila and Aldo Leopold Wilderness areas lie within the 3.4 million acre (1.4 million hectare) Gila National Forest in southwestern New Mexico north of Silver City. During his stint with the Forest Service in New Mexico, Leopold recognized that the rugged terrain, including steep slopes, deep canyons, and high elevation mesas, had, to a degree, preserved the area from the pressures of logging and grazing that were taking a heavy toll on much of the arid Southwest. Leopold understood that it is easier to maintain a small, pristine wilderness than to rehabilitate large, severely degraded areas.

Though protected naturally by the terrain, and by the Forest Service, nevertheless, by 1975, the Gila trout and Gila chub had experienced a steep decline in numbers. Only five small remaining—relict—populations of Gila trout were documented in high elevation headwaters of the Gila River drainage. That same year, the Forest Service initiated a policy, now known as Wildland Fire Use, of allowing lightning-ignited wildfire to burn without intervention, or with minimal management and containment, with the long-term goal of reducing fuel loads and eventually returning the forest to a regime of smaller, less severe fires.

"This is one of the first places that had a Wildland Fire Use Program," says Penelope Morgan, a professor of Fire Ecology and Natural Resources at the University of Idaho in Moscow, ID. "The Gila trout has survived with fire for millennia. All too often we assume that fire is detrimental to streams and fish," says Morgan, "but in the long run the habitat is sometimes benefited by having movement of logs and sediments, which contribute to pools and riffles." For the Gila trout and Gila chub, however, wildfire has on occasion swiftly undone efforts to preserve the few remaining populations.

"The Gila trout are less mobile than some fish," says Morgan. "If there is a refuge where they can re-colonize over the long term, they can recover." A series of wildfires in the late 20th century, however, resulted in the extirpation of some populations of Gila trout in isolated patches where there were no natural refugia. It was only through efforts to raise Gila trout in a hatchery environment, and aggressive intervention to translocate and restock fish, that certain genetically distinct strains of the trout survive today.



Horseback riding for recreation in the Gila Wilderness, 1922. Inspired by writings of Aldo Leopold, the Forest Service made the Gila Wilderness the first of many national forest wilderness areas. Credit: W.H. Shaffer, USDA Forest Service.

"Managers tend not to move the fish unless they are threatened," says Morgan. "They are trying to protect the fish, following the Endangered Species Act and local policy. The aim of the Wilderness Act is to manage in an untrammeled way."

In early spring 2003, an 118,000-acre (48,000-hectare) fire was managed with limited suppression near some of the few stream reaches supporting the Gila trout and Gila chub. "It started in April and burned all summer," says Jerry Monzingo, fishery biologist with the Gila National Forest. That fire eliminated most of the Gila chub in the only remaining stream within forest boundaries where they were found. “After the fire, we found a few chub in Turkey Creek,” says Monzingo. “We went back after some big ash flows and found no chub.” The chub are now found in only one patch of Turkey Creek within the wilderness areas, though there are several populations in Arizona. “The decision-making process of letting fire play its natural role was made by the district ranger and fire management officer on the district,” says Monzingo. “Resource specialists were not consulted for input.”

(Top) Interagency crew collecting Gila trout to evacuate. Mogollon Creek, 2003 Dry Lakes Fire Use Fire. After a 5-hour horseback ride into stream. (Bottom) Ash and debris flow in Turkey Creek (Gila chub stream) following the 2003 Dry Lakes Fire Use Fire. Credit: Jerry Monzingo.

Gila trout: Poster fish for conservation

The Gila trout (*Onchorhynchus gilae gilae*) was one of the first species recognized as endangered under the Federal Endangered Species Preservation Act of 1966. By 1975, the fish’s range had been reduced to five small relict populations in the upper stretches of the Gila River and in tributaries in the Gila and Aldo Leopold Wilderness Areas.

Within the protected area, where no logging or grazing has occurred in decades, the primary threats to the trout are threefold. High severity fire can be catastrophic, killing fish directly by raising stream temperatures and destroying riparian vegetation, and indirectly by triggering ash flow and debris slides into the stream beds and altering stream chemistry. A second threat is hybridization with rainbow trout and competition from brown trout, both of which are non-native. Perhaps the greatest threat, however, is loss of connectivity of stream habitats.

Thanks to hatchery propagation, restocking efforts, and removal of rainbow and brown trout by resource management agencies, the number of streams where the native trout were present was expanded to 14 by 1987. At the time, the U.S. Fish and Wildlife Service considered populations stable enough that the Gila trout was proposed for downlisting to threatened. A severe wildfire in 1989, however, extirpated one lineage of the fish from the Main Diamond Creek watershed, underscoring the continuing vulnerability of the fish to fire and post-fire effects.

There are four genetically distinct lineages of Gila trout. Since the 1930s, agencies have attempted to raise these fish in hatcheries. Two of the lineages are currently in production at the Mora National Fish Health and Technology Center, assuring the survival of these distinct, non-hybridized trout. The other two don’t thrive in the hatchery environment “We have been trying aggressive techniques to improve survival in the hatchery, putting rocks, boulders, and logs in the raceways so the fish have a place to hide,” says Monzingo. “With the two lineages that don’t do well in the hatchery, we translocate them from stream to stream. We try to conserve genetics, not just the species,” says Monzingo. “The Endangered Species Act doesn’t recognize hybrid species.”

Tracking fire severity

After a series of severe fires, natural resource managers in the Gila National Forest were keenly aware of the need for better information and predictive models of the effects of fire on fish to assist in management decisions. Responding on a fire-by-fire basis to threats to the fish of the Gila watershed is dangerous, and managers also need to juggle sometimes conflicting mandates to protect fish while continuing the progressive use of Wildand Fire Use for natural, wilderness values.

(Top) White Creek Mesa 2003 Dry Lake Fire Use Fire where it burned hot in the White Creek drainage, resulting in ash and debris flow. (Bottom) Ash and debris flow, Gila trout stream post-2003 Dry Lakes Fire Use Fire.
Credit: Jerry Monzingo.

In 2003, Zachary Holden, then a graduate student at the University of Idaho, saw for the first time satellite images of the Gila Forest, revealing scars from historical fires dating from 1984. Until then, the boundaries and extent of fire had been recorded on paper, not digital, maps. Holden realized that these satellite images, collected over a 20-year period, could be used to determine the ecological effects of those fires and to produce a "burn severity atlas." The idea was not new; the Forest Service was already beginning to use satellite imagery to monitor trends in burn severity throughout the United States. Concentrating on one regional national forest would allow land managers to respond to the specific, local need to protect endangered fish.

Holden and his dissertation advisor, Penelope Morgan, designed a study, supported by the Joint Fire Science Program (JFSP), to track the trends of 114 fires greater than 100 acres (40 hectares) over a 20-year period, 1984 through 2004, using remote satellite sensing, historical weather information, and on-the-ground assessments of fire severity.

The terms fire intensity, fire severity, and burn severity mean different things to different people. While knowing the severity and intensity of a fire during and immediately after fire is essential in managing wildfire and protecting fire fighters, Holden says that for understanding fire's ecological effects, the key term is burn severity. "When using satellite images to infer severity of burn, the important thing is the magnitude of ecological effects relative to prefire conditions." For the JFSP study, the designation "severe" was reserved for fires in which 75 percent or more of the overstory trees were dead from fire effects within one year post fire.

Remote sensing data were collected from National Aeronautics and Space Administration's (NASA's) Landsat 5 satellite, which was launched in 1984 and has gathered data nearly continuously with its Earth observation sensor, the Thematic Mapper. Burn severity is inferred by measuring the amount of radiation from the sun reflected off the ground surface. "Vegetation reflects certain wave lengths and absorbs others," says Holden. "Think in terms of a hillside covered with green trees before a fire. A lot of near infrared radiation is absorbed by the trees. When you remove the trees, less near infrared is reflected back because the soil absorbs the radiation." This information is used to determine a ratio or index to measure changes in overstory vegetation and soil characteristics. "If you want to know where there are severe, stand-replacing fires with potential for soil erosion and debris flows, this technology gives a crude, probabilistic assessment."

Analysis of the data reveals the two primary factors that determine the severity of burn in the Gila National Forest: climate and topography.

Climate: In the southwestern United States, regional and seasonal variations in precipitation in winter and spring are governed by oscillations of the warm, wet El Niño phase and the cold, dry La Niña phase in the Pacific Ocean. In late spring and early summer, cyclonic activity in the Gulf of Mexico ushers in the monsoon season. The spring fire season occurs during dry "windows" between these two drivers of precipitation. In addition, the summer storm season brings frequent lightning, especially to mid and upper elevation forests. When dry weather combines with frequent lightning strikes, conditions are ripe for large, severe fires.

The 20-year data showed an increase in the number of dry springs over time and an increase in the number and frequency of fires, though Holden notes that the earlier years of the study were relatively wet. Snow pack was found to have only moderate effects on fire extent and severity in upper elevation forest types and no impact on mid-elevation forests. It is unclear whether the observed variations in spring precipitation in these two decades are driven by natural Pacific oscillations or global climate warming. Considering the relatively short time frame of the study, Holden says he is not comfortable attributing this increasingly dry period to global warming. The number of dry days and consecutive dry days in the transitional spring season, however, is clearly an important contributor to increased burn severity.

Topography: Analysis of remote sensing data indicates that nearly 10 percent of the Gila National Forest experienced severe burns during the study period, mostly on north-facing steep slopes in high elevation mixed-conifer and spruce-fir forest. Using a statistical tool known as a Regression Tree Analysis, Holden found in mid-elevation forests composed of pinyon-juniper, ponderosa pine, and Douglas-fir, severe fire also occurred on northern facing slopes. "In the Southwest, there are incredibly steep ecological gradients from desert grassland to high elevations up to 8,500 feet with less solar radiation," says Holden. Higher elevation forests tend to be cooler and wetter, and burn less often. "When they do burn, they burn at high severity."

The researchers also used geographic information system technology to map the 21 patches where Gila trout occurred and those scheduled for restocking. Comparing those maps with the remote sensing data on burn severity helps determine those streams where severe burns may result in post-fire effects such as ash and debris flow, which can destroy downstream habitat.

Mass soil movement, Upper West Fork Gila River following the 2002 Cub Fire. High flows since have moved a lot of the material downstream. Credit: Jerry Monzingo.

The results suggest that the best strategy to benefit the Gila trout is to expand the size of existing habitat patches in the Gila River and Mogollon Creek drainages. The tributaries that support fish in these two waterways provide increased connectivity, allowing the fish to migrate and seek refuge in case of fire. In smaller, isolated streams with high potential for debris flow, the ability of fish to survive is compromised, and translocation and restocking with the specific lineage native to those streams may be required.

Translocating fish during a fire, however, is risky for personnel as well as fish. People ride in on horseback, shock and gather fish, and transport them to helicopters for removal to a safe location. "In some of these places it takes a day to ride in," says Monzingo. "Evacuation is stressful when the fire is right there."

(Top) Helicopter with tank used to evacuate fish. (Right) Helicopter retrieving fish hauling tank once loaded with fish. Fish are transported to Mora National Fish Hatchery via the hatchery truck. Credit: Jerry Monzingo.

Remote sensing's future

The Landsat 5 satellite has outlived its expected lifespan and is nearing the end of its mission. Holden also analyzed a number of other remote sensing platforms that are already deployed and may be used to gather information in the future. Two Earth observation satellites are promising for future monitoring: QuickBird, a commercial satellite launched in 2001, and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), launched in 1999 in a collaborative venture with NASA and the Japanese government. Both are somewhat higher resolution than Landsat. "QuickBird and ASTER have smaller pixels and higher resolution," says Holden, but there is a cost. "At higher resolution you lose sensitivity to different wavelengths of reflected radiation."

While the remote sensing data give a historical picture of past fire severity, Monzingo says managers could also take better advantage of inferences from satellite data on an annual basis in remote wilderness areas where it is difficult to monitor burn severity on the ground. "When we let these fires burn, we need to monitor to determine whether we are meeting the objectives for the fire."

In recent years, Monzingo has seen improvements in coordination efforts between fire management planners and resource specialists. "Every year prior to fire season, we sit down together and do preplanning, discussing where and under what conditions we would let fire burn from natural ignitions." Having buy-in from multiple stakeholders means a reduction in internal conflict. "I'm a big supporter of wildland fire use," Monzingo says, "as long as all of the resources, especially rare ones, are given consideration during the decision-making process. I learned if you are not invited, insert yourself, don't wait for somebody to come ask you."

Management Implications

- Managers need timely, current information to plan for fire season and assess the results of management decisions after fire season, particularly when balancing the needs for natural fire and habitat for fish.
- Natural resources specialists must be actively engaged with fire management officers and decision makers in annual fire planning before the fire season.
- Remote sensing data should be complemented by field data to determine the magnitude of post-fire ecological effects on soil characteristics, hydrology, and tree mortality.

Further Information: Publications and Web Resources

Holden, Z.A., P. Morgan, M.A. Crimmins, R.K. Steinhorst, and A.M.S. Smith. 2007. Fire season precipitation variability influences fire extent and severity in a large southwestern wilderness area, United States. Geophysical Review Letters 34, L16708.

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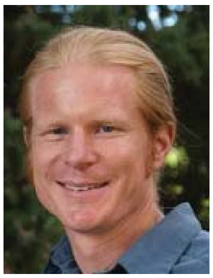

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